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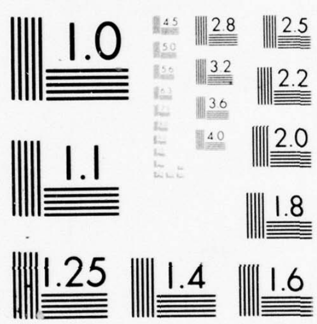

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PROGRAM MANAGEMENT COURSE INDIVIDUAL STUDY PROGRAM

BATTLEFIELD STANDOFF TARGET
ACQUISITION SYSTEM (SOTAS):
AN EXAMPLE OF ENHANCED SYSTEM EFFECTIVENESS
VIA *HUMAN ENGINEERING*

STUDY PROJECT REPORT
PMC 77-2

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DEFENSE SYSTEMS MANAGEMENT COLLEGE

STUDY TITLE: BATTLEFIELD STANDOFF TARGET ACQUISITION SYSTEM (SOTAS): AN EXAMPLE OF ENHANCED SYSTEM EFFECTIVENESS VIA HUMAN ENGINEERING

STUDY PROJECT GOALS:

Review program philosophy and procedures which have been successfully used in the SOTAS program to incorporate human factors engineering into a balanced approach for meeting mission objectives. By summarizing these philosophies and procedures it is intended that meaningful guidance can be obtained and applied in future programs where human performance is critical to success.

STUDY REPORT ABSTRACT:

Human Factors Engineering should be applied early in the development cycle of those programs where human performance plays a significant part in the operation and support of the weapon system. In many programs, including SOTAS, effective human performance has been critical in meeting basic mission functional requirements. In SOTAS this need was reflected in the design of a combined man/machine system with sufficiently quick response and high target predictive accuracy to be effective as a target acquisition sensor. Human performance has also been found to be critical in assuring the effective integration of the developmental system into the operating force structure in terms of both operational interfacing and cost.

Philosophy and procedures which have been successfully used in the SOTAS program to incorporate human factors engineering into a balanced approach for meeting mission objectives are reviewed. By summarizing these philosophies and procedures it is hoped that some practical guidance can be obtained and applied in other programs where human performance is critical to success.

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BATTLEFIELD STANDOFF TARGET ACQUISITION SYSTEM (SOTAS): AN EXAMPLE OF ENHANCED SYSTEM EFFECTIVENESS VIA HUMAN ENGINEERING

Individual Study Program
Study Project Report
Prepared as a Formal Report

Defense Systems Management College
Program Management Course
Class 77-2

by

George E. Webber
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November 1977

Study Project Advisor
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EXECUTIVE SUMMARY

For weapon systems where human performance plays a significant part in successful operation and support, human factors engineering can be profitably applied if it is initiated early in the development cycle. For many such programs, including SOTAS, optimal human performance has been critical in meeting basic mission functional requirements. For SOTAS, this need has been reflected in the design of a combined man/machine system with sufficiently quick response and high target predictive accuracy to be effective as a target acquisition sensor. Human performance has also been found to be critical in assuring the effective integration of the developmental system into the operating force structure in terms of both operational interfacing and cost.

Personal interviews of SOTAS program team members and analyses of program reports have been utilized to investigate the philosophy and procedures which have been successfully used in applying human factors engineering to the SOTAS development. These procedures were incorporated early as a part of concept development and system design. Throughout the validation process of demonstrating integrated hardware, human factors have been considered in the allocation of operational functions and procedures, and in the design of workspace, displays, keyboards and other elements of the total man/machine interface. The development of a detailed system simulation has also been a very successful tool in optimizing system design and in establishing effective training procedures and personnel requirements.

In the SOTAS development as in some other programs, human factors engineering also plays an important and politically sensitive role in test and evaluation of the system. In this case much of the test and evaluation procedures have been designed by the human factors engineering team in conjunction with the Operational Test and Evaluation Agency. In this kind of role the credibility of an unbiased human factors team is important in assuring acceptability of the test evaluations.

This report attempts to review and summarize some of the management philosophy and human engineering procedures which have been successful in

the SOTAS program in providing a balanced approach for meeting mission objectives. By reviewing these philosophies and procedures it is hoped that some guidance can be obtained and applied in other programs where human performance is critical to success.

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Essentially every weapon system in existence is dependent in some significant way upon an integrated "human subsystem" for its effective operation and/or its maintenance and support. This critical role of the human subsystem together with the greatly increased proportional expense of human resources makes human engineering analysis and design a critical discipline in effective weapon system development. Although this area of technical development is becoming increasingly important it remains relatively unfamiliar to most program managers (1). It is the purpose of this report to present an overview of management philosophy and application techniques which have been effectively used to incorporate human factors engineering into the Standoff Target Acquisition System (SOTAS) development. The lessons learned, both good and bad, from this type of practical example, can provide guidance for program managers in the future.

Human factors engineering is defined in Army Regulation AR-602-1 as a comprehensive technical effort to integrate all personnel characteristics (skills, human performance, behavioral reactions, biomedical factors, training implications) into Army (Service) doctrine and systems to assure operational effectiveness, safety and freedom from health hazards (2). DOD Directives indicate that human factors engineering should be implemented early in the weapon development cycle utilizing a total system design viewpoint which focuses upon the Personnel-Material-Mission Performance in the development and operation of the system (3). The Human Factors Engineering development program begins with a long range development plan which is incorporated at an early stage as part of the overall Program Management Plan (PMP). Throughout the weapon development cycle this plan will interrelate closely with the System Design Plan, the Test and Evaluation Management Plan (TEMP), the Integrated Logistic Support Plan (ILS), and other elements of the overall program. The progression of human factors engineering tasks which are typically addressed during the sequential phases of weapons development are indicated in Figure 1-1. Elements of program documentation used to define and characterize the Human Factors Engineering Plan are also indicated.

FIGURE 1-1 TYPICAL ARRAY OF HUMAN FACTORS ENGINEERING TASKS VERSUS PROGRAM DEVELOPMENT PHASE

	CONCEPTUAL PHASE	VALIDATION PHASE	FSED PHASE
ACTIVITIES	*Develop HFE plan and incorporate into Program Plan *Conduct candidate system analysis including gross partitioning of man/machine functions *Estimate gross impact of candidate system concepts on performance, personnel reqm'ts,training	*Detailed partitioning of man/machine functions *Tentative identification, allocation, sequencing of operator and maintenance tasks *Define training requirements for operations and maintenance *Define and demonstrate HFE procedures and criteria *Define man/machine interface requirements *Define HFE research to support operations and maintenance *Define training procedures and aids *Define HFE performance evaluation tests	*Final detailed task analysis, operation and maintenance task sequencing *Man/machine interface design and fabrication *Develop tech documentation and manuals *Design training procedures and aids for operation and maintenance functions *Establish personnel MOS *Design and conduct HFE performance evaluation
DOCUMENTS	*DCP *HFE plan *PMP *LOA or contract with HFE agency/contracor *LOA with User agency	*DCP *HFE Plan *PMP *LOA or contractor with HFE agency/contractor *ROC with User agency	*DCP *HFE Plan *PMP *TDR (training and device requirement)

The benefits of effective Human Factors Engineering in program development can be staggering both in terms of total system performance or effectiveness, as well as in terms of system life cycle cost (LCC). In today's typical weapon system, the operation and support costs of the system represent, on the average, over 50 percent of the total life cycle cost (4). For most of these systems, personnel and personnel related costs comprise the biggest portion of Operations and Support (O&S) costs. In the scenario of an all volunteer defense force, personnel related costs are currently the fastest growing portion of LCC and therefore worthy of a major amount of our attention during design and development.

For the SOTAS system in particular, effective Human Factors Engineering was equally important in assuring an effectively integrated man/machine system capable of meeting the performance requirements demanded by the Standoff Target Acquisition Mission requirement. In this case Human Factors Engineering played a significant role in developing and evaluating a system which had to have quick response and accurate target predictive capability to be acceptable to the "user" as a practical target acquisition sensor for weapon control purposes.

This report is intended to provide some insight into aspects of program management philosophy and methods of human factors engineering which have been successfully utilized in developing the SOTAS system. This is done in the hope that variations of these methods and techniques might be useful in other programs as well. The report is organized into four sections. The first of these outlines the general human factors problem to be addressed in SOTAS and summarizes some of the accomplishments to date. The second section describes the SOTAS system and its mission objective while the third section provides details of the human engineering process as applied to the SOTAS program. The final section summarizes conclusions and formulates recommendations for human factors engineering in future programs.

SOTAS AND HUMAN FACTORS ENGINEERING

The SOTAS concept is one which is very much dependent upon effective integration of both human as well as material subsystems for maximum performance. Because of this, the need for Human Factors Engineering was

recognized early in the program by both the Program Management Office and the DA staff. In addition to the usual requirements for minimizing O&S costs of the system it was critically important in SOTAS that the total system be capable of "near-real-time" response and accurate target positional prediction so that it would be "bought" by the "user" (5).

The Human Factors Engineering plan was conceptualized by the PM and the Department of the Army System Coordinator (DASC), and was integrated into the overall SOTAS program management plan. Honeywell Systems and Research Center in Minneapolis was brought in as an outside contractor to develop and implement the Human Factors Plan. The Human Factors Engineering activities had to be effectively integrated as a part of: (a) system/hardware design and development; (b) operational procedure development; (c) test and evaluation; and (d) personnel and training development, as a part of ILS development.

In accomplishing these objectives, the SOTAS Program Management Office (PMO) was faced with a number of potential problem issues, including: (a) free and open communication between contractor team members; (b) "objective status" of the Human Factors Engineering team in the eyes of the "user"; and (c) effective integration of human factors analysis and design into hardware design. The means by which these and other problems were solved or avoided is the subject of this report.

HUMAN FACTORS SUMMARY IMPACT ON SOTAS

Early in development the SOTAS concept for achieving the standoff target acquisition mission was recognized by program management as being a "man-critical" approach (6). By organizing a program team which included Human Factors Engineering as well as system and hardware design engineering, a balanced developmental approach resulted, which served to optimize the effectiveness of the system in meeting mission objectives. Working together, this team has successfully demonstrated by developmental and operational tests the feasibility of SOTAS in meeting mission requirements of acquiring, tracking and predicting targets from long standoff with high accuracy and near-real-time response.

In meeting this objective human factors related accomplishments in

particular have been focused to date in four areas including system functional analysis, workspace analysis, simulation development, and operator/crew procedures and training. Ensuing activities will address the broader picture of integrating SOTAS into the total tactical battlefield scenario with emphasis being given to development of optimal SOTAS/DTOC interfacing.

Human Factors Engineering has had a significant impact upon the SOTAS system configuration and design. Some of the most important issues effectively resolved have included the following(7): (a) control van layout geometry and design has been specified for near-optimal man/machine through-put efficiency using operational test data, full scale mockups and simulation test data; (b) information through-put efficiency has also been improved with greater integration of system operation functions on fewer displays by using "higher order" mission oriented graphics for both operator and OIC consoles; (c) keyboard designs have been developed which decrease the use of raw alpha-numerics and increase the use of mission oriented function keys to achieve greater through-put; (d) development of near optimal workspace design within the constraints of control van geometry to reduce operator fatigue and increase accuracy and through-put; (e) specification of automated or semi-automated target "picking" and tracking software and positional predictive software to decrease operator workload and increase through-put; and (f) development of data summarization and reduction software.

The human factors work has also had a pronounced impact upon system manning as well as operating and training procedures. The following points illustrate a few of the most important developments in this area(8): (a) development of an extensive computer simulation of the SOTAS system which has been effectively used as a tool in man/machine interface design and as a prototype training aid; (b) establishment of basic four-man operating team consisting of two "search and tracking operators (STO), one "Officer in Charge" (OIC), and a "communicator"/standby operator (C); (c) empirical development of efficient functional portioning between operators, OIC and hardware/software; (d) expansion of the OIC's interactive and capability by including a combined map digitizer and target

status display at the OIC station; (e) development of operating procedures and guidelines for operators and OIC; (f) development of detailed, documented crew training procedures using system simulation; characterization of desired training background (MOS) for crew members.

Future human factors activities in the development of natural and efficient DTOC/SOTAS operational interfaces are expected to greatly expand the tactical utilization of SOTAS for both standoff target acquisition and reconnaissance missions.

SOTAS SYSTEM DESCRIPTION - SECTION II

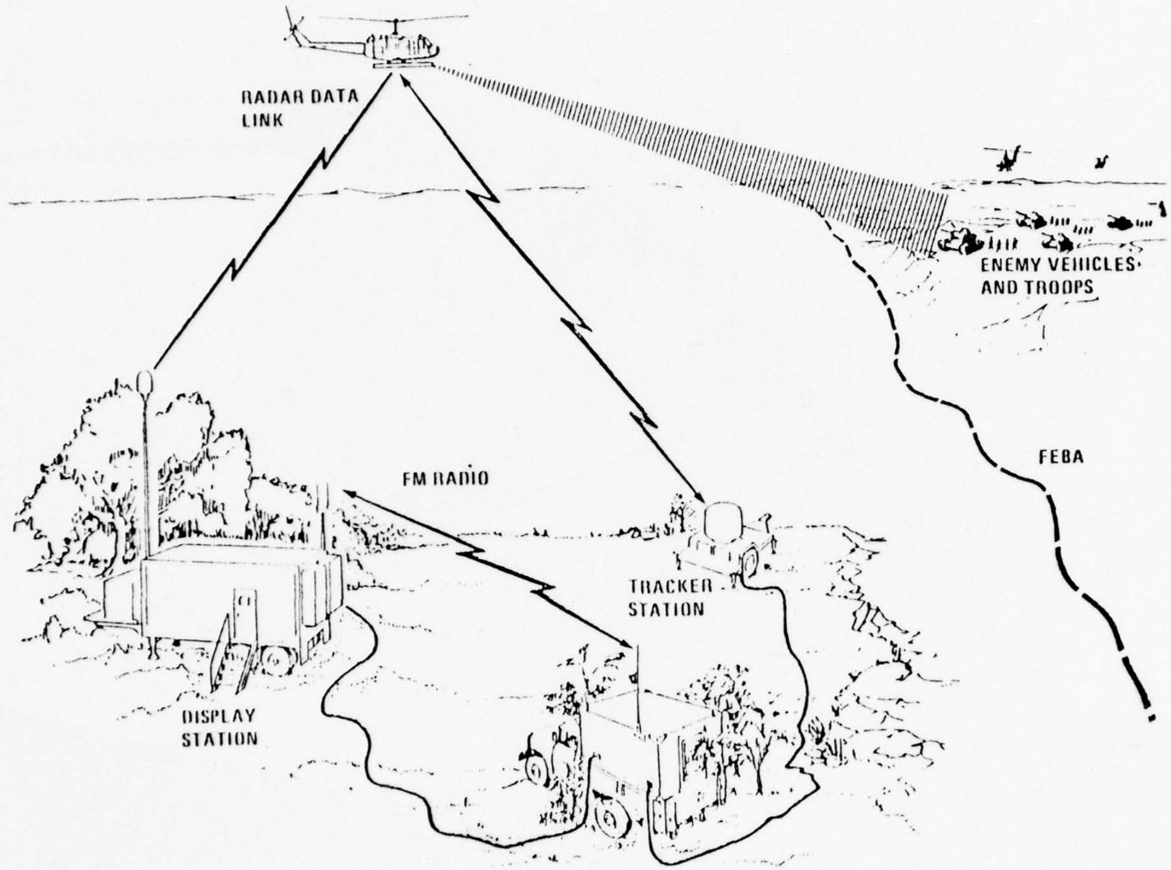
SYSTEM REQUIREMENTS

The Standoff Target Acquisition System (SOTAS) is an Army Division heliborne radar and ground control/display system that detects and tracks moving ground targets in forward battle areas as illustrated in Figure 2-1. The fundamental objectives of the system are: (a) to provide an all-weather target acquisition capability with sufficient accuracy in tracking and predicting target activity with emphasis on the second level enemy staging areas behind the forward edge of the battle area (FEBA); (b) to provide an all-weather reconnaissance capability for surveillance of enemy operations including second level stages areas beyond the FEBA (7).

A number of important guidelines are to be observed in the process of developing the SOTAS system to achieve the above objectives. These are : (a) minimize the SOTAS development cycle with a goal of interim deployment of the system within four years after program initiation; (b) minimize manpower, training and support costs in operation; and (c) utilize a minimal program office staff. The program objectives, together with these implementation guidelines, meant that effective, efficient, and probably long term contractor relationships would have to be developed, and that off-the-shelf hardware or variations thereof, would be required as a baseline in developing the system.

The functional operation of the system is indicated in the functional block diagram shown in Figure 2-2. In this scenario, the helicopter provides an elevated platform from which a high resolution radar with "moving target indicating" (MTI) capability can view the battlefield on the opposite side of the FEBA. The helicopter's exact position is monitored at all times by a ground based tracking radar which is located in the tracker van as shown. This Tracker Subsystem continuously communicates the helicopter's position back to the helicopter, using an RF "up-link". The data processing assembly within the helicopter then takes the MTI battlefield imagery data derived from the airborne radar

FIGURE 2-1 SOTAS SYSTEM CONCEPT GEOMETRY



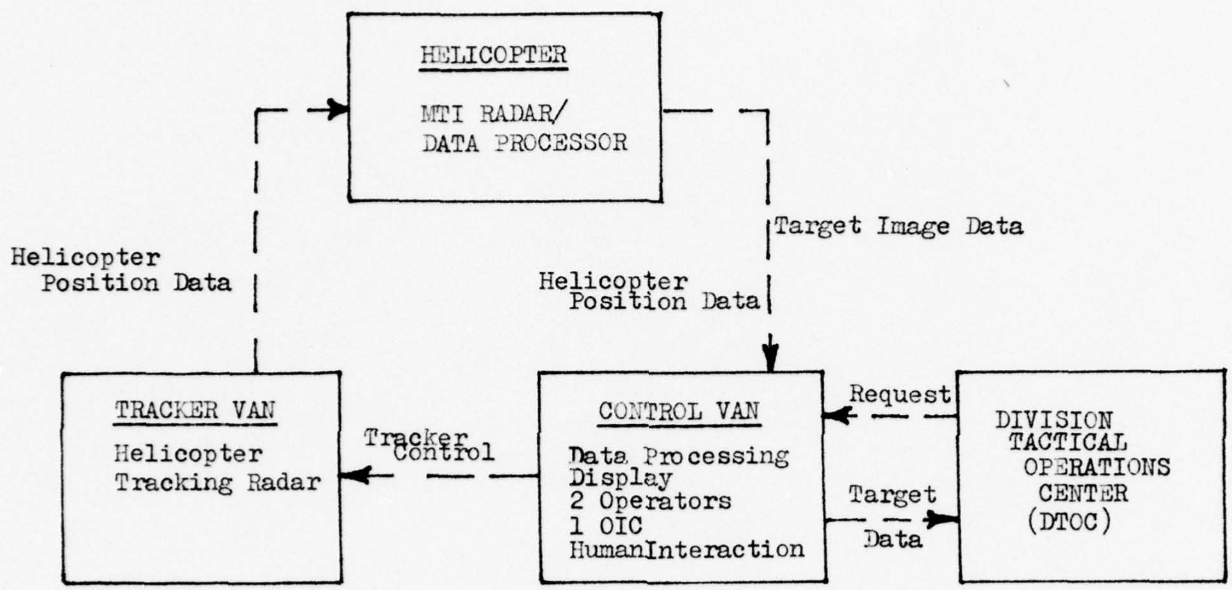


FIGURE 2-2 SOTAS SYSTEM FUNCTIONAL BLOCK DIAGRAM

and together with helicopter position data, transmits this information back down to the ground Control Van, using a separate RF "down-link".

Within the ground Control Van, the raw target Video data and the position reference information are then processed and selectively displayed under the complete control of a human operator(s). The human operator(s) also control the viewing scene of the airborne radar by commanding helicopter flight maneuvers via a voice link to the pilot. The control van operator(s) also controls the selection and formating of wide area surveillance situation reports and target data which is sent to the Division Tactical Operating Center (DTOC). All of the above operations are of course performed in essentially "real-time".

HUMAN ENGINEERING REQUIREMENTS OF THE SOTAS SYSTEM

After familiarizing ones' self with the SOTAS system description, it is immediately clear that the "man-in-the-loop" is extremely critical to the successful operation of this particular system. The basic goals to be achieved in developing the man-machine system design were: (a) to minimize target data "through-put" time so that SOTAS could effectively serve as a moving target acquisition system useful in directing weapon fire; (b) to verify the operational accuracy requirement especially in azimuth resolution necessary for the system to perform as a target acquisition and reconnaissance sensor; (c) to minimize manpower, training and support requirements in order to minimize out-year O&S costs; and (d) to design the total SOTAS man-machine system to achieve the shortest possible development/deployment schedule.

The human engineering aspects of this program had to be incorporated from the start and had to proceed in a completely interactive partnership with hardware development. The management process for successfully accomplishing this rather unique task is the heart of this paper.

The human engineering design of a system is something that in many cases is neglected or at best put off until it is too late to impact hardware or operational/support design. However, in the SOTAS system the critical operation and support requirements demanded an early consideration of "human subsystem" in conjunction with other hardware. If, for example,

the target data "through-put" time could not be reduced to near real-time so that the system could perform as a target acquisition system, there was a real chance that the program would be killed early in its development (9).

The basic functional areas which were addressed by the "human engineering team" were: (a) personnel subsystem design, including crew composition, training requirements and procedures, workspace layout and crew station configuration, target display formats, target data processing and tracking procedures; (b) SOTAS operator/machine interface design leading to specification of the interface hardware (displays, keyboards, etc.) and software (data processing and formating algorithms, etc.) necessary to transform raw target imagery into data suitable for DTOC utilization; (c) DTOC Interface Design including specification and evaluation of communication links to elements of the DTOC as well as determining utility of distributed control input in selected areas of DTOC; and (d) training, system evaluation and support design, including the development of training hardware and software, development of system evaluation procedures, and the design of maintenance and support concept (10, 11, 12).

PROGRAM DEVELOPMENT PLAN AND STATUS

The SOTAS program concept was initiated by the Deputy Chief of Staff for Research Development and Acquisition (DCSRDA) in late 1973 based upon capabilities of the radar system which had just been developed by General Dynamics as part of the Advanced Longrange Attack Radar Program. It is probably worth pointing out that the user Training and Doctrine Command (TRADOC) was not directly involved at this time, but was first officially involved in the program when the SOTAS study advisory group (SAG) was formed in June of 1975. In March of 1975 the SOTAS program was officially approved by the Director of Defense Research and Evaluation (DDR&E) and the SOTAS project office was established by the Development and Readiness Command (DARCOM) with the Electronics Command (ECOM) Radar Lab as the lead development lab. An abbreviated program development task sequence is shown in Figure 2-3.

The SOTAS program was somewhat unique in that since much of the basic radar sensor hardware and the basic system concepts had already been developed,

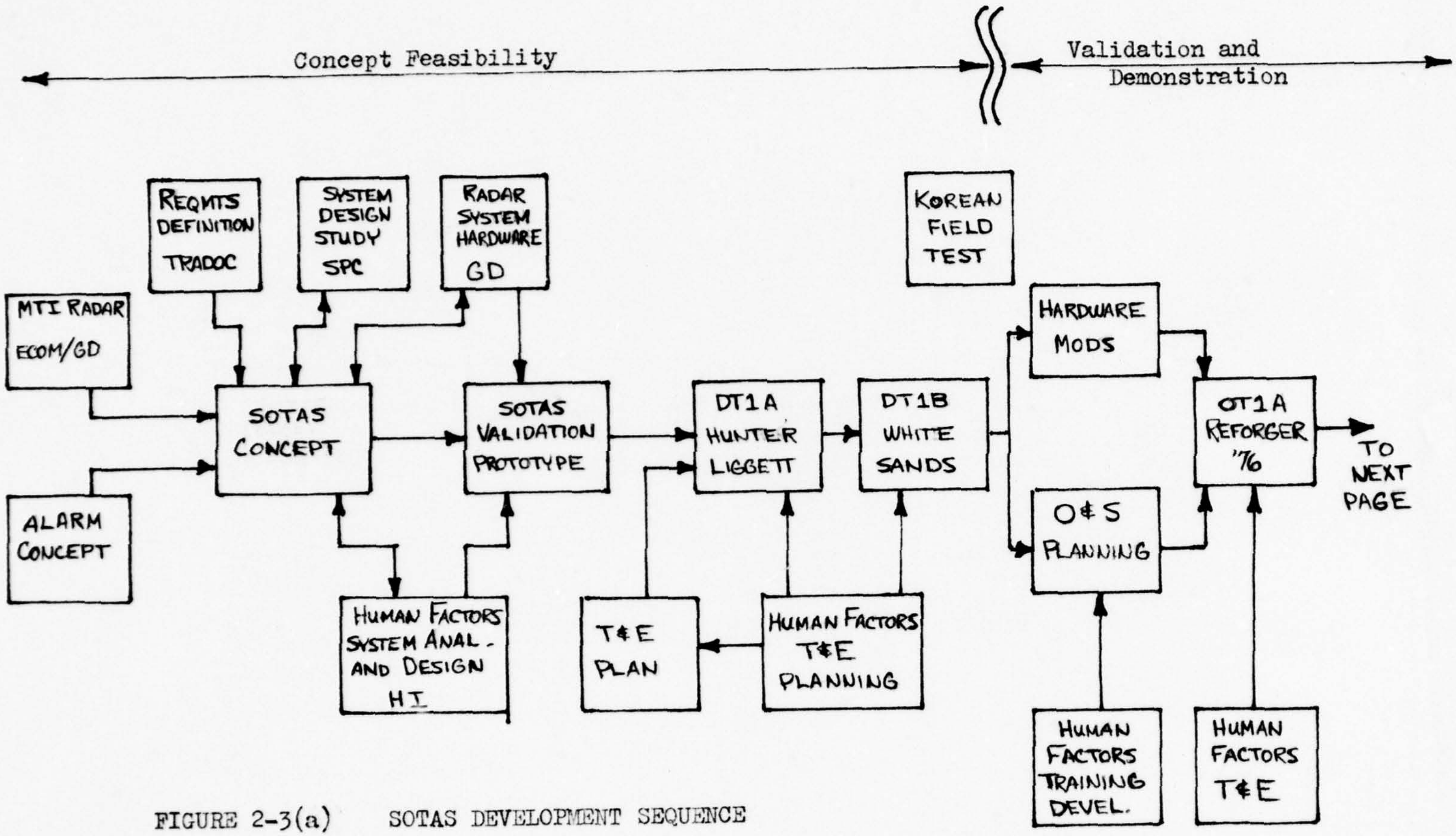


FIGURE 2-3(a)   SOTAS DEVELOPMENT SEQUENCE

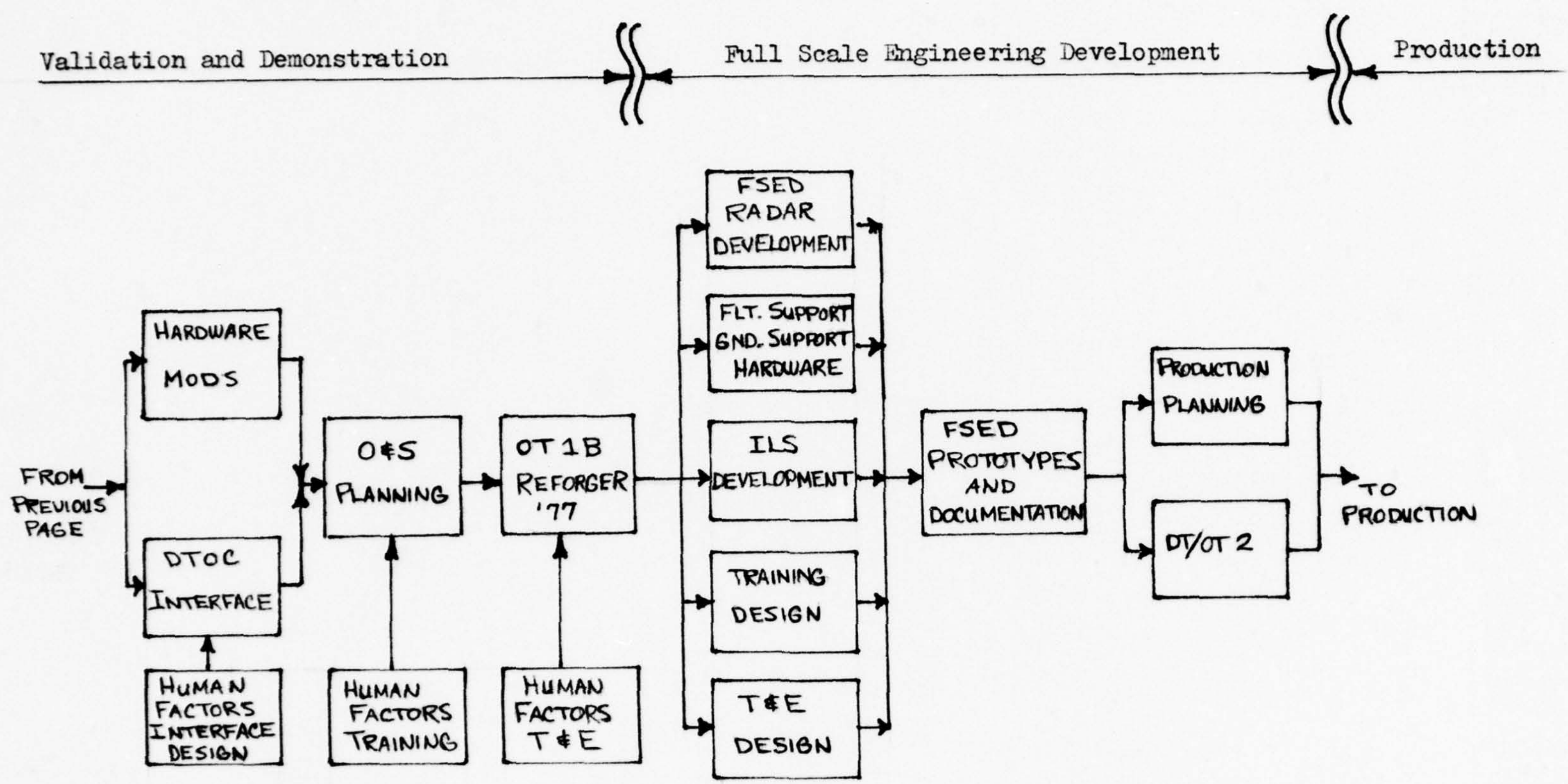


FIGURE 2-3(b) SOTAS DEVELOPMENT SEQUENCE

it was possible for the program to move almost instantly into the concept validation and demonstration phase. At this point, SOTAS was not considered a major technology program and was operating on 6.2 and 6.3A funds under a broad Operating Capability Objective statement from TRADOC. In light of this, an Army System Acquisition Review Council (ASARC)-I review prior to moving into Concept Validation was considered unnecessary.

The Concept Validation phase was fundamentally focused upon getting ready for Developmental and Operational Testing (DT/OT)-I with the purpose of resolving the following questions:

(a) Can sufficient azimuth resolution be achieved for target acquisition and surveillance using a single heliborne sensor or will a dual platform (trilateration) concept be required?

(b) Can the system "through-put" time be sufficiently reduced to "near-real-time" using software data processing and other "operator aids" so that SOTAS can be effective in directing fire against potential targets?

(c) Is the target tracking accuracy and response time of the SOTAS concept suitable for weapon delivery?

(d) Can operator and support requirements be sufficiently simplified in the SOTAS operating concept so that the system can be cost effectively deployed in the field? (9)

As of the present time (September, 1977) the SOTAS system concept, using a single platform heliborne MTI radar sensor, has been successfully demonstrated during developmental testing at Hunter Liggett and White Sands respectively, and at operational field evaluations conducted in Europe during Reforger '76. The system is presently undergoing further field operational evaluations in Europe during Reforger '77. The program was established as a "major Army" program in late 1976 at the request of DDR&E and a DCP is being formulated based upon a firm Requirement for Operational Capability (ROC) now being issued by TRADOC. An ASARC-II review is planned in March, 1978 before advancing the program into Full Scale Engineering Development.

Summarizing from the program plan presented in Figure 2-3, the key

development achievements in the program to date have been: (a) concept initiation by DCSRDA in January, 1974; (b) TEMP and Development Strategy structured using Human Engineering Design Concept-April, 1975; (c) "DT1A"-Hunter Liggett Test-successful demonstration of adequate azimuth accuracy using single heliborne system-important milestone in achieving user support-April, 1975; (d) "DT1B"-White Sands-successful demonstration of "real-time" operating capability;

(e) briefings to General DePuy (TRADOC) and General Brady (CACDA) result in "official" user support of SOTAS program; and (f) "OT1A"-Reforger '76-successful operational demonstration of SOTAS in Europe-September, 1976.

SOTAS PROGRAM MANAGEMENT ORGANIZATION

The SOTAS program is officially organized within the Army and Office of the Secretary of Defense (OSD) as shown in Figure 3-1. However, as is the case with most project offices, SOTAS' actual operating structure within the Department of the Army and OSD is somewhat different. The structure which most accurately represents the principal operational interfaces involved in the program is shown in Figure 3-2. SOTAS utilizes a very "lean" program matrix structure and as with all other organizations, activities can be categorized into the usual hierarchy of "strategic planning" activities, "coordinating" activities, and "operational" activities. Within the SOTAS office these functions are overlapped as illustrated in Figure 3-2. Within the "strategic" activities, the long range planning and strategy formulation is really done primarily by the DASC and the Program Manager, who seem to operate together virtually as co-program managers. Through the DASC they also maintain a very close working relationship with the technical coordinating officer at DDR&E in much of these planning and initiating tasks. This very active and aggressive role of the DASC is somewhat unique in program management. In the SOTAS project, a strong DASC and a strong program manager working together as a team appear to have directly contributed to the success of the otherwise very "lean" program staff matrix.

The Study Advisory Group of course also played a significant role in strategic planning activities. However, this role was less of an "initiating" role and more of an "advisory" and "reviewing" role. The SAG was made up of members from DDR&E, ASA (R&D), DCSOPS, DCSRDA, DA (PA&E), DA (Comptroller), DA (OpsRes), ACSI, DCSLOG, TRADOC, CACDA, DARCOM, Air Force, Marine Corps, and the SOTAS PM.

The coordinating activities within this overall management structure were largely handled by the DASC and the Program Manager. For downward coordination an informal and flexible but effective relationship was developed between the DASC, PMO personnel, ECOM functional support personnel, and contractor personnel. Program coordination within this group was accomplished using frequent informal face-to-face program reviews.

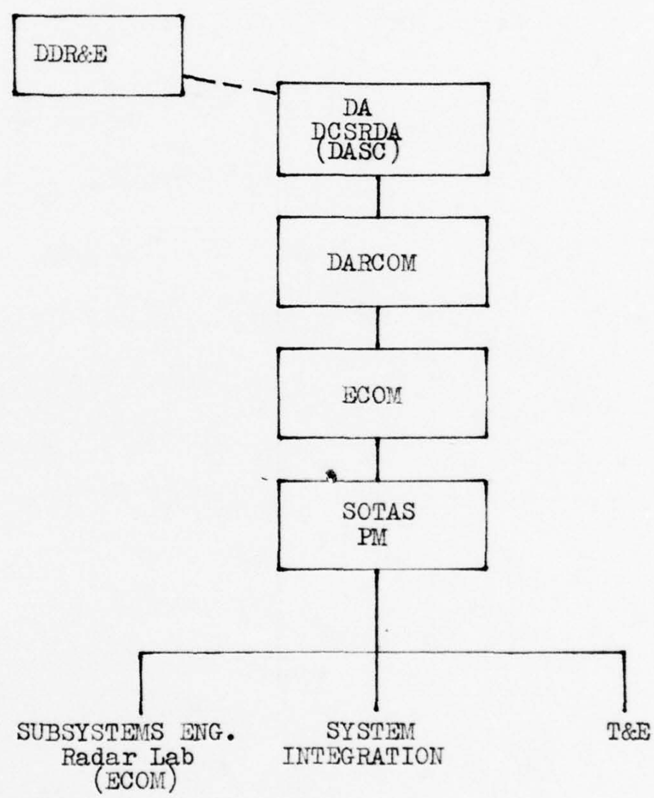


FIGURE 3-1 OFFICIAL SOTAS ORGANIZATION WITHIN DA AND OSD

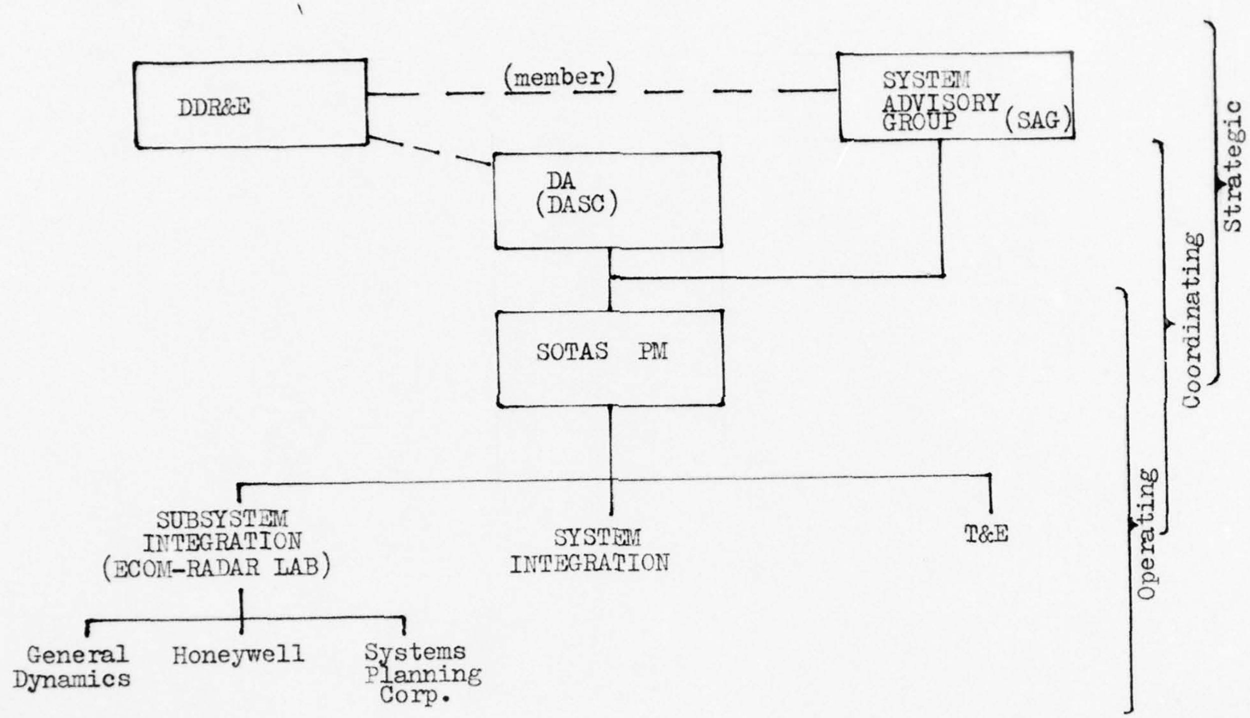


FIGURE 3-2 SOTAS OPERATING ORGANIZATION

Upward "coordinating" activities were accomplished by the DASC/OM using the SAG members and their contacts. The DASC was the most active in this arena, but required the constant support of the program manager.

The routine "operational" activities of the SOTAS program were necessarily structured almost entirely around contractor activities together with the interactions of the PMO staff. The program manager was of course intimately knowledgeable and involved in these activities. It is unique in this program that the DASC officer also maintained a close relationship with the operational groups. Because of the close coordination between the DASC and the PM, this interaction of the DASC at the operational level does not appear to have detracted from the leadership and control functions of the PM in this area. Frequent face-to-face contact between contractor teams was forced by the PMO through the use of frequent on-site reviews. Although the travel requirements became significant many critical interface design problems were in this way either avoided or solved early in development (6).

MANAGEMENT PHILOSOPHY

The management philosophy of the SOTAS program is largely set by the Program Manager and the DASC. Although this philosophy is one which seems to be working effectively in light of the program constraints, it is not necessarily the only successful philosophy which might be employed. It might certainly be different with a different combination of individuals involved.

A major part of the developmental philosophy of the SOTAS program is to integrate existing or "nearly existing" hardware subsystems in order to demonstrate a sufficiently accurate, real-time standoff target asquisition system in the shortest possible development time. This developmental philosophy has necessitated a lean but dynamic program organization which is adaptable to change and which is able to progress rapidly with a minimal amount of bureaucratic impediment. In order to achieve this, a management philosophy is utilized which maintains an informed and very interactive relationship within the program organization including the contractor teams and the DASC officer. Program control still remains very definitely

in the hands of the program manager/DASC although all team members are able to freely contribute. The PM, the DASC and program element managers both within the PMO and contractor's organization seem to be very personally compatible, which allows interpersonal exchange at all levels without hazards of interpersonal risks.

This kind of dynamic relationship in the program is necessary in achieving program development goals, but can also lead to potential problems in contractual relationships and documentation if these areas are not carefully addressed. The management information system in the SOTAS program is not rigidly structured but seems to be successful. It consists basically of informal but dependable communications between principal individuals at each of the team member organizations. The telephone is invaluable in this communication but frequent face-to-face review meetings among all team member principals at the various organization facilities has also proven effective. Within the PMO itself, weekly staff meetings have served to effectively insure dissemination of pertinent information gathered by individuals. Telephone logs, meeting minutes, monthly technical reporting, as well as interim and final tasks are utilized and disseminated to team members. Standard monthly funds status reporting has been used on the present cost-type contracts as opposed to Cost-Schedule Control System Criteria (C/SCSC) reporting. The informal telephone and face-to-face cost monitoring techniques have proven most effective to date. Costs have consistently been controlled to budget baseline (6).

A very important aspect of the program management philosophy resulted from specific issues with the "user" during the early phases of the program prior to DT/OT1 results. The specific issue was the capability of the SOTAS system to provide very accurate target location data in moving targets in "near-real-time", so that the information could be effectively used by a tactical commander for fire-control or weapon guidance. In resolving these issues with the user, the program office was very much dependent upon the human factors engineering team to optimize the total man/machine system from the standpoint of "throughput" response and target location and prediction accuracy. In addition the program office was dependent upon the human factors team to assist in designing, conducting and documenting a totally unbiased DT/OT1 test and evaluation sequence

which wuld be beyond criticism (9).

The result of all of this was a somewhat unique program management philosophy which required that the human factors engineering contractor maintain, as much as possible, a neutral position regarding system advocacy. Thus he was discouraged during the initial phases of the program, from participating in any other hardware developmental aspects of the program where future production potential might jeopardize his unbiased position. This is a critical issue in the PMO/contractor relationship and is one that must be very well understood by both parties from the very beginning. In this case the issue arose because the Human Factors contractor team was involved in defining and conducting test and evaluation as well as the design of the man/machine system.

Another issue which of course also impacts this type of "hardware exclusion" relationship is that of "technology transfusion" between contractors. This can occur whenever two or more of the contractors on the development team have similar corporate capabilities and proprietary rights are involved. When this situation occurs baseline criteria for information exchange must be established and mutually understood. It may also be necessary to define and agree upon hardware exclusion relationships through the FSD phase to the point where the product baseline is defined and necessary rights-in-data are acquired. The hazard of not taking these kinds of precautions can be "stifled" communication between development team members and contractor protests during contractual procurement resulting in disastrous delays.

HUMAN FACTORS ENGINEERING PLAN

The human factors engineering in the SOTAS program was originally incorporated in order to develop an optimal man/machine interactive system which would: (a) achieve sufficiently short target throughput time in order to meet "real-time" requirement for fire control ; and (b) demonstrate adequate azimuth accuracy in target identification and cueing from long standoff so that the system is valuable in reconnaissance as well as weapon guidance (11).

Since the SOTAS system concept is dependent upon the human operator team working in conjunction with the hardware subsystem, human factors design optimization was critical in achieving the above performance requirements. Once these performance characteristics were demonstrated to the satisfaction of the "user" community, the emphasis in the human engineering design effort was able to be directed at optimizing the training and support design of the system.

Thus, the human factors involvement in the SOTAS system has been directed in the following primary areas of activity: (a) SOTAS System Functional Analysis and Functional Partitioning between Hardware/Software/Human Subsystems; (b) Human Subsystem Design including Machine/Operator/DTOC Interfacing; (c) Training and Operational Support Design; (d) Hardware and Software Design Specifications; and (e) T&E Design, Execution and Analysis (7). See Figure 3-3.

This organization of human factors design activities is fundamentally similar to that utilized in various other weapon development programs within DOD (13). One fundamental difference, however, is the significant dependence upon human factors design and documentation of test and evaluation tasks in order to demonstrate to the "user" community the capability of the system to achieve high accuracy with "near-real-time" response.

The first of the human factors task areas addressed the functional analysis of the total SOTAS system within the constraints of its mission requirement. The objective is to obtain an optimal functional partitioning of tasks between hardware, software, and human operator as well as DTOC subsystems (14). Informational requirements and priorities are defined at all interfaces. The human subsystem design task has addressed such issues as crew composition, operating procedures, I/O design requirements including keyboards, graphics and software aids, work area layout design and intercommunication design.

Training and Operational Support Design has to date primarily concentrated upon training requirements, procedures, crew performance evaluation, and training simulator development. In the future, as part of this task the human factors team will also address operational support and maintenance

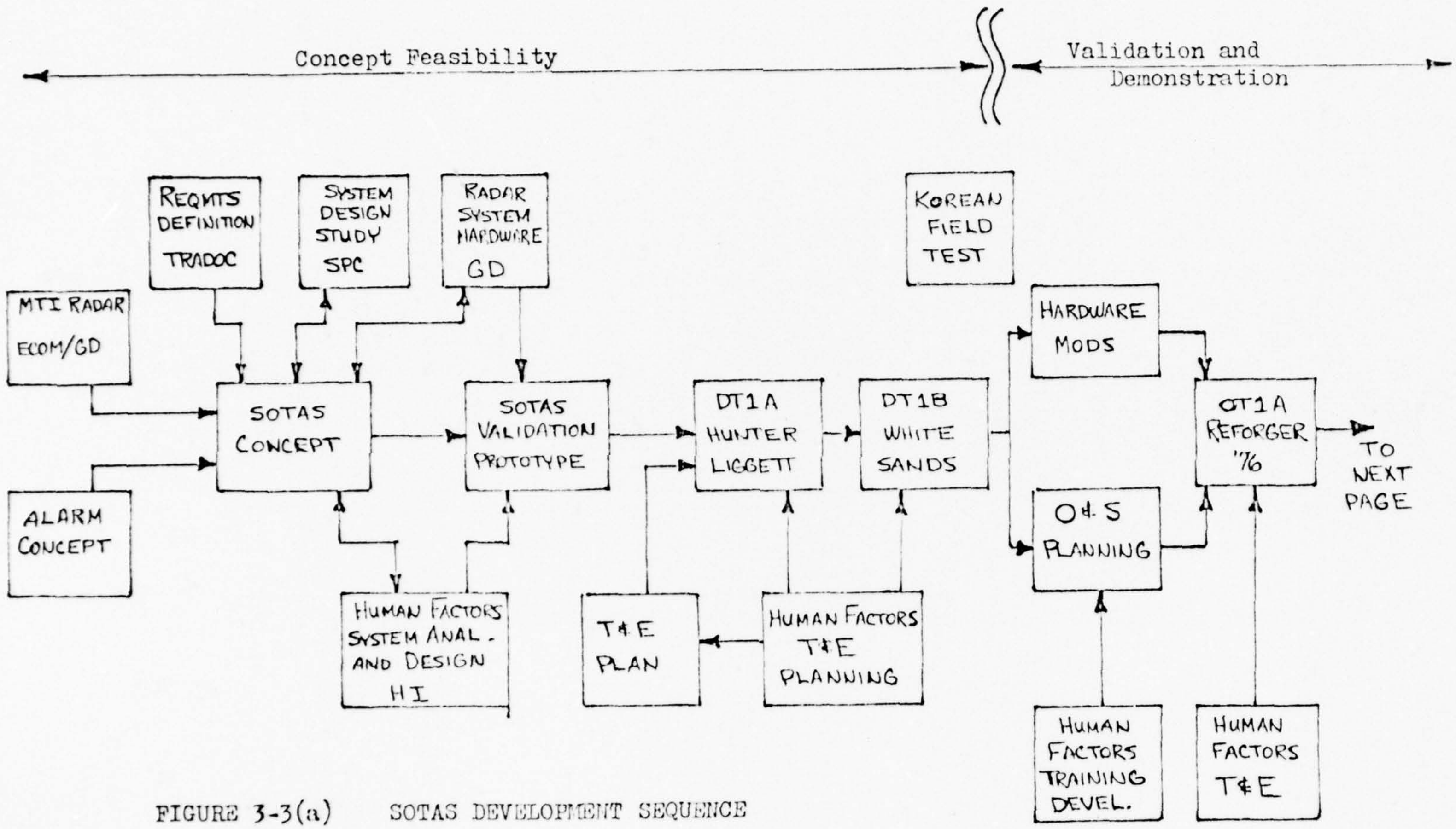


FIGURE 3-3(a) SOTAS DEVELOPMENT SEQUENCE

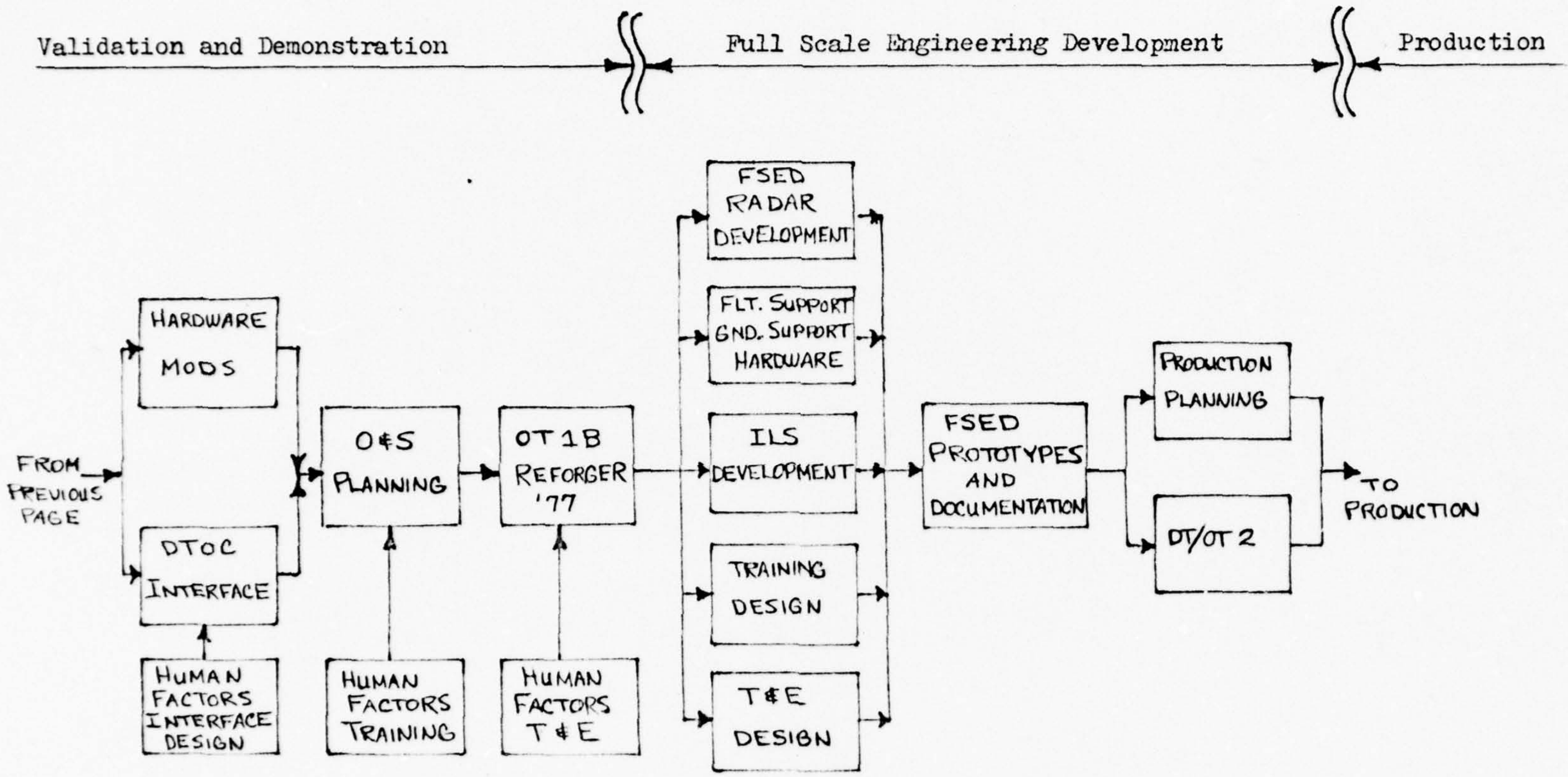


FIGURE 3-3(b) SOTAS DEVELOPMENT SEQUENCE

requirements and procedures.

Much of the human factors design effort has resulted in the partial design specification of many of the prototype hardware and software items including the SOTAS Control Van layout, graphical displays, keyboards, and software aids. In addition, as part of the SOTAS program the human factors team has been tasked with major involvement in test and evaluation planning, execution and analysis. This role is a sensitive one and is one which can compromise or limit the human factors contractor in terms of his future participation in some hardware development opportunities.

The sequence of the human factors analysis, design and development activities is structured approximately as shown in Figure 3-3, relative to the SOTAS program development phasing. The resolution of the two primary critical issues in the Program concerning "real-time" response capability and azimuth accuracy capability really occurred as a result of DT1 and OT1 testing as illustrated.

MANAGEMENT OF TECHNICAL DEVELOPMENT TASKS

The human engineering tasks which were outlined in Figure 3-3 can be grouped into roughly three categories, including: (a) system technical development tasks; (b) test and evaluation tasks; and (c) operational and support development tasks. From this viewpoint of human factors engineering, the system technical development tasks include the system functional analysis, operator workspace analysis, and the resulting impacts of these analyses upon system design.

Functional Analysis

The objective of functional analysis was to describe system operation in terms of the tasks of the crew and the mission of the system (14). Three types of analysis were used by the design team, including: (a) information requirements analysis; (b) decision analysis; and (c) activity analysis. The functional analysis studies assumed a baseline operating team consisting of (a) a "search operator" responsible for battlefield surveillance and target detection; (b) an "attack operator" responsible for target tracking and positional prediction; and (c) an "OIC" responsible for target identifi-

cation, target tactical maneuvers and DTOC interfacing. In both analytical situations and in an actual field test scenario at Hunter Liggett, information transfer was flow charted in order to trace the course of data in the system from display hardware through the processing necessary (either human or computerized) to use that information in the fulfillment of the tactical mission. Considerable attention was given to the interface of display hardware, the SOTAS operators and the SOTAS OIC.

Decision analysis was conducted to identify the quantity and quality of decisions necessary in the fulfillment of system mission. System derived information required at each decision point in an overall "decision tree" was identified and related to decision making process and tactical output. Activities carried out by the crew while performing their assigned functions were analyzed using time samples based upon observation of SOTAS in the field environment. The analysis was used to judge the relative importance of various operator activities on the system mission and the relationship of these activities and crew workload during system operation.

Operator Workspace Analysis

The objective of this task was to define the physical arrangement of SOTAS equipment and crew stations within the SOTAS control van (14, 15). The methodology for doing this utilized the earlier functional analysis of crew activities to develop graphical "link analysis". A "link analysis" is a systematic way to summarize operator interactions graphically. The technique also incorporated the geometry of the operator and equipment layout so that layout advantages and disadvantages could be assessed as a function of the physical arrangement of operator stations and personnel. An exhaustive catalog of possible layout geometrics was developed and evaluated. Obviously unacceptable concepts were discarded.

Remaining concepts were evaluated for their ability to fit within the SOTAS control van envelope. Space requirements for equipment including maintenance access provisions were determined. Anthropometric data for space requirements for the crew members established the remaining requirements for van space. These were incorporated in the final group of candidates defined.

The final candidates were evaluated by a scaled judgements technique. The technique used experienced raters in a full-scale mock-up of the van and

equipment. When the best configuration was determined by this evaluation, it was developed further through the mechanical specification stage to determine any problems of implementation that would require minor modification of the proposed layout.

Resulting Impacts on System Design

As a result of the system functional analysis and workspace analysis, a number of system design specifications were defined. These included: (a) greater integration of system operation functions with fewer displays through the use of "higher order" mission oriented graphics for both operator and OIC consoles. This reduction in the number of displays helped focus operator's attention, reduced fatigue, and accelerated data through-put; (b) development of display keyboard designs which decrease the use of raw alpha-numerics and increase the use of mission-oriented function keys in order to speed through-put; (c) development of near optimal workspace design within the constraints of control van geometry to reduce operator fatigue and increase accuracy and through-put; (d) development of automated or semi-automated tracking hardware/software to decrease operator workload and increase through-put; and (e) development of data summarization and reduction software as well as software for "cursor" placement and advanced predictions of target location.

MANAGEMENT OF TEST AND EVALUATION TASKS

Test and Evaluation Objectives

The human factors involvement in test and evaluation was focused upon the exploration and evaluation of relationships between system hardware and software as it affected training, procedures, and performance of SOTAS operators and crew. The objective of this involvement was to collect data concerning the effectiveness of the human/system interface given the existing system configuration and to provide evaluation criteria for future system design recommendations (16). Human factors test and evaluation has been conducted as a part of developmental testing at Hunter-Liggett and White Sands, and as a part of operational testing during Reforger '76, and more recently during Reforger '77. In each case specific objectives of human factors testing and evaluation have centered upon: (a) the nature of the operator/OIC/system interface and the effectiveness

of established crew procedures; (b) the roles of the SOTAS cadre as they affect the SOTAS/DTOC interface; and (c) the effectiveness of the SOTAS training program and manning levels during system operation and the evaluation of levels of crew experience. The human factors test and evaluation was a major sub-element of the overall DT/OT test plan. The program's long term test and evaluation management plan was coordinated through the Test and Evaluation element manager within the Program Management Office and utilized the Operational Test and Evaluation Agency (OTEA) in organizing and conducting the operational test and evaluation.

Test Methodology

To realize the human factors test and evaluation objectives five data collection techniques were developed, each yielding information in different aspects of system operation (16). They were: (a) automated data; (b) performance diaries; (c) through-put logs; (d) interviews; and (e) audio/visual recordings. Automated data using operator function key presses was a measure of operator use of system hardware/software resources. Observational through-put logs contained a record of the amounts of information at three functionally defined human processing points (two operators, one OIC) within the SOTAS van and the response to DTOC information requests. This record served as a baseline for assessment of the relationship between available information and information flow, and productivity in terms of mission tasking. Exercise event time lines (performance diaries) provided a parallel accounting of environmental factors, system status and cadre activity. The structured interview was used to obtain evaluative data from members of the SOTAS cadre. Finally, audio/visual recordings were aimed at providing correlations of the crew/system in operation during variable tasking.

Data obtained by each data collection method was applicable to more than one objective. As an aid to analysis and documentation, technical areas were identified within each of the test objectives and the data were integrated according to the technical area. The resulting matrix is depicted in Table 3-1.

Automated Data - Automated data consisted of operator keyboard entries and their associated times and was used in characterizing: (a) the distribution

TABLE 3-1 TYPICAL TEST DATA MATRIX (16)

	Objective I	*Objective II*	*Objective III*
Technical Area	Workspace	SOTAS/DTOC Interface	Manning Levels/ Shift Schedules
Data Sources	- Interviews - Performance diaries - Audio/Visual	- Interviews - Throughput logs - Performance diaries	- Interviews
Technical Area	Crew/System Interface	SOTAS Performance	Training
Data Sources	- Automated measures - Performance diaries - Interviews - Throughput logs	- Throughput logs - Performance diaries - Interviews - Automated measures	- Automated measures - Interviews - Performance diaries
Technical Area	Workload		
Data Sources	- Interviews - Throughput logs - Automated measures		

of operator activity between system control, time compression activities, target tracking functions, target path predictions, range/azimuth determination, graphics generation, and error generation and correction; (b) the target file case and rate of target processing using file life data, number of target files being simultaneously processed, total number of files deleted and file efficiency as described by the ratio of simultaneously processed files to target through-put; (c) the number of target picks made by operators on each target and their confidence in those picks as described by number of target picks by file, number of deleted picks, and time delays in picking targets; and (d) the general system parameters including duration and frequency of system "down" time, and amount of time spent and number of keypresses made in each display scale.

Performance Diary - The performance diary was a method used by observers in the SOTAS van to characterize: (a) the event time line data to record the occurrence(E) and timing (T) of tactical events and the response of members of the SOTAS crew; (b) crew performance data describing the mission (M) of the operation (i.e. target acquisition, command and control, surveillance), OIC activity mode, Operator activities (i.e. set-up, target search, target prediction, target tracking); and (c) critical incident data (i.e. man/machine interface, hardware/software function, information flow, workspace environment, crew procedures, other critical incidents). Performance diary data were recorded using data formats such as that shown in Figure 3-4.

Through-Put Log - System through-put is defined as the number of pieces of target information transmitted from the SOTAS van to the DTOC in a particular period of time. As such, system through-put permits analysis of system effectiveness in terms relevant to SOTAS' tactical impact and operator/crew information processing. In the SOTAS evaluations system, through-put was broken into four parts: (a) the number of moving objects on each operator display (T_0A and T_0B); (b) the number of targets processed by each operator (T_1A and T_1B); (c) the number of targets evaluated by the OIC (T_2); and (d) the number of targets passed to DTOC by the OIC (T_3). Specific data on targets were further broken out as being descriptive, coordinate, or predictive information. The amount of SOTAS time spent on

FIGURE 3-4 PERFORMANCE DIARY DATA FORMAT (16)

SUMMARY – SHIFT TIME______ TO____			
VIDEO RUN	COUNTER	TIME	TAPE #

AUDIO RUN	COUNTER	TIME	TAPE #

INCIDENT REFERENCE	B#__ TIME____	B#__ TIME____	B#__ TIME__	
#__ TIME____	#__ TIME____	#__ TIME____	#__ TIME____	#__ TIME__

TOTAL MISSION TIME	TA	S	CC	O
TOTAL MODE TIME	UP	DOWN	OFF	

OIC ACTIVITY TIME	TO	DS	SM	OP	C

OPA ACTIVITY TIME	SUM	SOS	SOP	SOT	SOA	SO

OPB ACTIVITY TIME	SUM	SOS	SOP	SOT	SOA	SO

a target from initial observation to DTOC handoff, called through-put time, was recorded for both SOTAS initiated targets and DTOC information requests. Figure 3-5 illustrates a typical through-put data recording format.

Interview and Audio/Visual Recordings - Structured interviews were conducted with SOTAS operators and OIC's to provide comments, insights and observations. The interviews were structured around three types of questions: open-ended, two-way, and multiple choice. Open-ended questions were used to obtain data on issues where large variability in response was anticipated. Two-way questions were used where preferential judgement between two alternatives was required, and multiple choice questions were used in making the respondent consider a specific range of alternatives.

In the initial test plans, audio and visual recordings were planned in order to obtain real-time information on operator and OIC activities. Where these were conducted they were found to be unsatisfactory since they tended to interfere with normal crew operations.

Typical Test and Evaluation Results

Each of the data collection methods described yielded information on different aspects of system operation. During data analysis each bit of datum was interpreted with reference to other data elements and with reference to the three basic human factors test objectives. Conclusions derived from this analysis were based upon supportive data from at least two of the different data collection formats. A few of the more important conclusions derived from early Reforger '76 DT/OT human factors testing were associated with the following technical areas:

(a) Workspace (16) In general, it was found from all test data that the SOTAS operator's existing workspace was adequate. However, it was found that the OIC needed an integrated work station to support his unique task requirements, primarily in tactical operations (see Figure 3-6). To perform the target evaluation task the OIC needs both the map digitizer and status display with both internal and external communications activities integrated at his work station; (b) Crew/System Interaction (16) The system provided workable imagery immediately upon establishment of the data link with the heliborne sensor. The target data storage was adequate. Operators demonstrated less confidence in automated target entry relative

FIGURE 3-5 THROUGH-PUT DATA RECORDING FORMAT (16)

DATE__________

TIME______ TO______ OBS______

CREW OIC______ A______ B______ RTO______

WATCH STARTED MISSION

	LEVEL		
T_0A			
T_0B			
	# COORD	# PRED.	# DESCR.
T_1A			
T_1B			
T_2			
T_3			
START		FINISH	

SUBTOTAL

THRUPUT RESPONSE TIME

NAME/NO.	S/D	RESPONSE T.	
			COORD.
			PRED.
			DESCR.

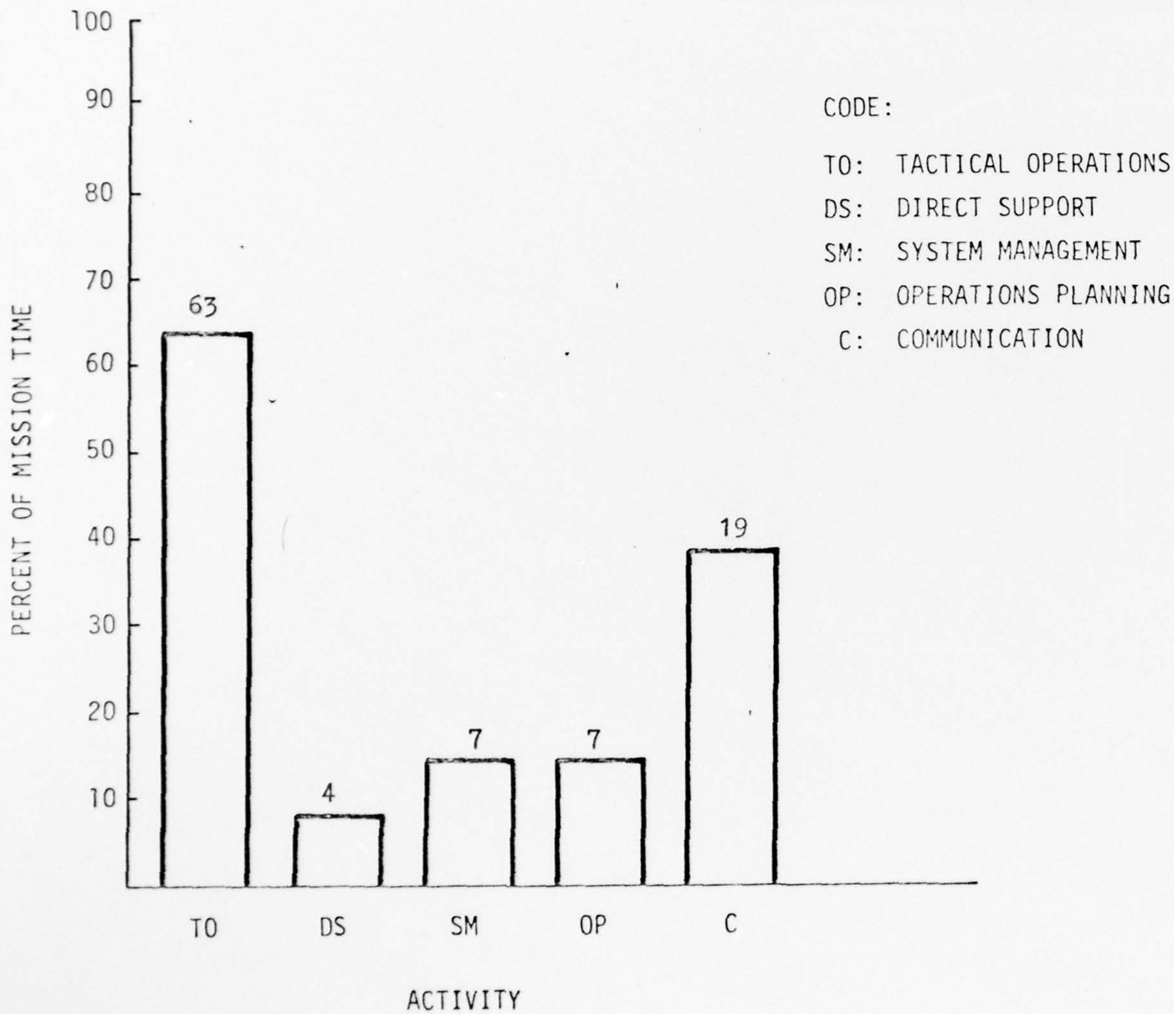
	LEVEL		
T_0A			
T_0B			
	# COORD	# PRED.	# DESCR.
T_1A			
T_1B			
T_2			
T_3			
START		FINISH	

SUBTOTAL

THRUPUT RESPONSE TIME

NAME/NO.	S/D	RESPONSE T.	
			COORD.
			PRED.
			DESCR.

FIGURE 3-6 PERCENT OF TOTAL MISSION TIME PER TYPE OF OIC ACTIVITY (16)



to manual entry which lengthened through-put time. Excessive operator time and activity was involved in manipulation of time-compressed imagery. Operators spent a majority of their time in OIC-directed search and track operations; (c) Workload (16) Operators were able to meet Reforger '76 tasking requirements without exceeding capabilities of the operator or the system, although the frequency of operator-initiated target entries declined after 45 minutes into the mission. High workloads were mostly associated with activity periods between missions including map registration, DTOC/helicopter coordination, mission planning, graphics creation, etc. OICs spent about 20% of their time in external communications and about 80% in target development. Much of this target development activity included duplication of operator image processing. The OICs workload capabilities were not exceeded; (d) SOTAS/DTOC Interaction (16) External communication links between SOTAS/DTOC during Reforger '76 were inadequate and resulted in delays, "cross-talk" data misinterpretation, and limited tasking of SOTAS by DTOC; (e) System Performance (16) The SOTAS system was very reliable with only about 90 seconds or two percent total "down-time" during the Reforger '76 operation. In addition to this, target information which was developed and passed to DTOC, met and exceeded specific mission requirements in terms of response time, adequacy and accuracy. Operator errors during operation were quite low—at about four percent; and (f) Training and Crew Shifts (16) Procedural training for operators using training simulators was readily transferred to field system operation. Training procedures also seemed to minimize the effects of differences in background experience, level of previous training and military grade of the SOTAS cadre. The effect of differing MOS also seemed to be minimal although artillery and intelligence would initially seem to be intuitively preferred. During initial periods of team operation, differences in OIC styles caused some problems in information filtering and coordination, but this seemed to be resolved quickly and naturally. The basic crew size of two operators and one OIC appears to work out well although during the Reforger '76 testing it was found that a "stand-by" operator was almost essential for recording functions which emerged during deployment. The "eight on/sixteen off" shift and rotation schedules were adequate for Reforger '76 in terms of fatigue as evidenced by errors,

through-put reduction, etc. However there was considerable "off-line" time between missions in these tests. Continuous twenty-four hour mission coverage could cause potential manning problems.

MANAGEMENT OF TRAINING AND OPERATIONAL PLANNING (17)

Within the general area of operation and support planning the primary involvement of the human factors engineering team has been placed in the definition of operating procedures, crew composition and crew training. The criteria for establishing recommendations in each of these areas was developed both through actual operational testing and, perhaps more importantly, through simulated system operation and evaluation. In the latter case a very complete software simulation of the system was developed. This provided not only an essential design aid for optimizing human performance, but in itself also served as a basis for developing training simulators in the future.

Training and Operational Simulation (14)

The complete SOTAS simulation consists of two principal elements including the training element and the SOTAS game. The training simulation is designed to provide exercises through which SOTAS crew members can exercise simulated equipment to find and tag enemy targets, interpret SOTAS imagery, and transmit target information in a usable form to the DTOC.

Crew Composition and Procedures

The basic crew composition for the SOTAS control van was developed and refined based upon observed performance during simulated system evaluation and actual operational testing. An optimal crew size was evolved to consist of four crew station positions as follows: (a) two search and tracking operators (STO); (b) one Officer-in-Charge (OIC); and (c) one communicator (C). It was also found desirable to have one liaison officer (LO). However, in actual deployment this role will likely be implemented by DTOC personnel. A minimum of three crews would be required for twenty-four hour operation.

The primary activities of the search and track operators is to detect, track targets, and generate attack information consisting of predictions of future target position for use in fire control.

The Communicator is actually a standby STO operator who provides assistance to the OIC in communications external to the SOTAS van. He also performs map plotting and record keeping tasks as assigned.

The OIC is responsible for organizing target data into patterns of target information for transmission to the DTOC. The data is organized in response to priorities, criteria, and directives established by cognizant elements of the DTOC. The OIC also supervises the workload and activities of the search and track operators.

The two phases of SOTAS system operation include: (a) the on-line operation during which the airborne platform is operating and imagery is being

generated in real time, and (b) the off-line operation when the radar platform is not being used and stored imagery from prior on-line periods is being analyzed.

Training Objectives

Fundamentally, the SOTAS training objectives provided a learning procedure by which an operator or OIC trainee with minimal advance training could be provided with basic skills necessary to operate the SOTAS system in the field. A system training simulation presently forms the primary training vehicle for providing these basic skills to the trainee. The total training system design concept in SOTAS is three-dimensionally organized around: (a) instructional content modules; (b) instructional method modules; and (c) instructional assessment modules as illustrated in Figure 3-7.

Instructional Content Modules - Five instructional content modules were utilized, including System Orientation, Basic Skills Acquisition, System Management, Crew Integration, and Tactical Integration. Specific topics addressed within each module are illustrated in Table 3-2.

Method Modules - Instructional methods were evolved by observing trainee performance after exposure to several different combinations of training techniques. These included classroom instructions, audio-visual presentations, system simulations, and workshops. The principal audio-visual techniques which were found most useful included video-tape, vugraphs, and conventional graphics in the form of tables, flow-charts, diagrams, and pictures. Much of this material together with instructional text material was integrated into training manual documents and effectively utilized in classroom and workshop training sessions. Classroom and workshop sessions were primarily used for training crew members in areas of system operation and management. The simulation training consisted of two parts including:(a) a simulated multi-day battle sequence involving a division size attacking force, and (b) a number of shorter tactical scenarios for specific exercises in basic skills in operating the equipment, processing target data, system management and crew coordination. Typical simulation exercises are indicated in Figure 3-8. Typical nature and content of the system simulation employed is described in another section.

FIGURE 3-7 THREE-DIMENSIONAL MODEL OF THE ORGANIZATION OF SOTAS CADRE TRAINING (17)

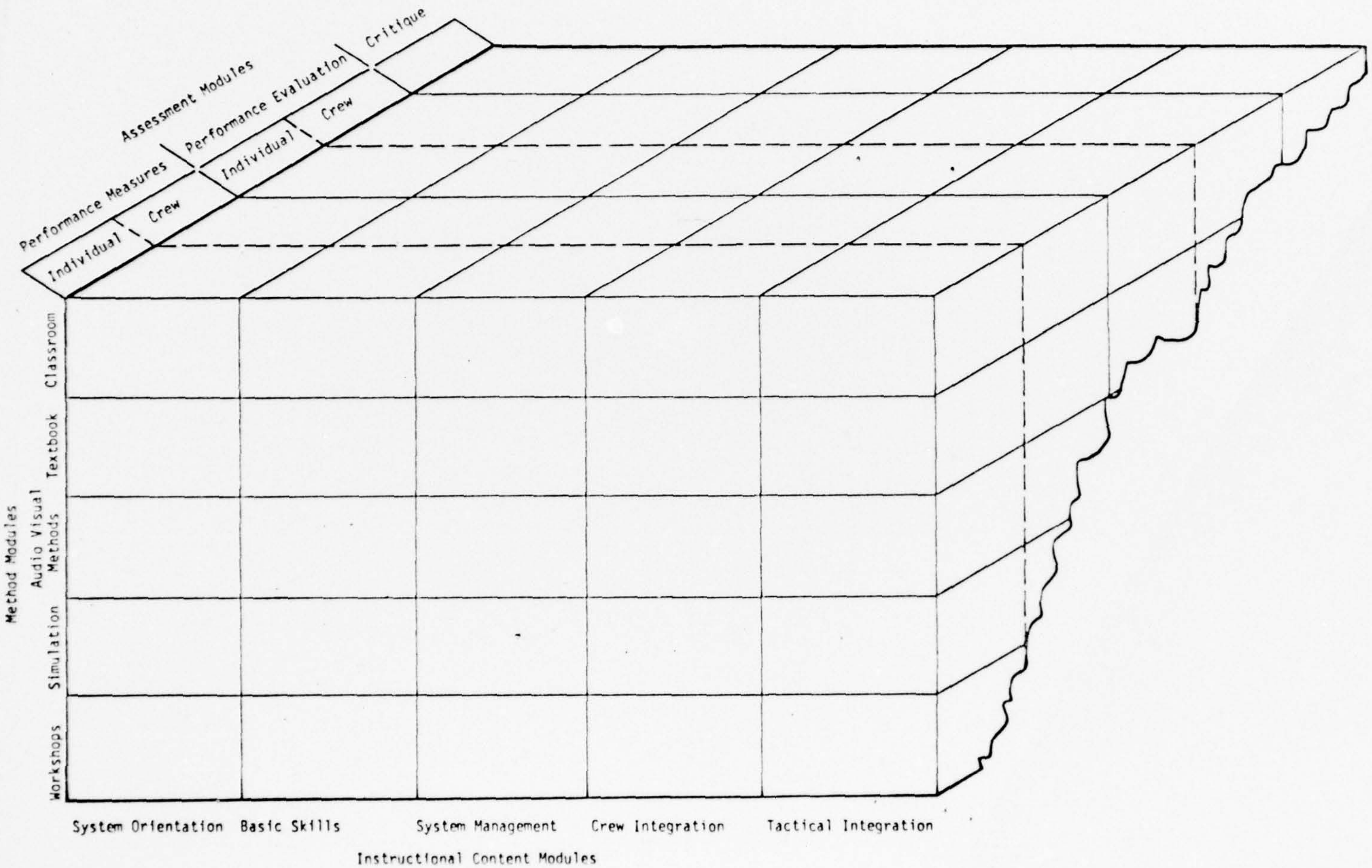


TABLE 3-2 UNITS OF INSTRUCTION FOR INSTRUCTIONAL CONTENT MODULES (17)

System Orientation

- System Overview
- SOTAS Training Briefing
- SOTAS Mission
- SOTAS Description
- Crew Positions

Basic Skills Training

- Tactical Imagery
- Tactical Environment
- Search/Track Console Operation
- Modes of System Operation
- Communication Procedures
- System/Van Operation

System Management

- Tactical System Configuration
- Crew Supervision and Coordination
- Operator Workload Management
- Helicopter Positioning and Coordination
- Emergencies and Malfunctions
- DTOC Interface Management
- Target Processing Management
- On-Line/Off-Line Task Distribution

Crew Integration

- Tactical System Setup
- Target Signatures and Priorities
- Target Development and Through-Put
- Interoperator Data Transfer
- OIC/Operator Coordination
- OIC/LO Coordination and Information Transfer
- Emergencies, Malfunctions, and Recovery Procedures

Tactical Integration

- Divisional Level Scenario
- Simulated SOTAS Mission Involving Surveillance, Target Acquisition, and Command and Control

FIGURE 3-8 TYPICAL SIMULATION EXERCISES (17)

- Simulation Description
  - Honeywell Configuration
  - Reforger SOTAS System
  - Interim SOTAS System
- Target Imagery
  - Target Signatures
  - Tactical Deployments/Dispositions
  - Tactical Formations
  - Target Classification
    1. Target Number
    2. Target Type
       a. Velocity
       b. Terrain Correlation
  - Tactical Inference
- Search/Track Console Operation
  - Keyboard Layout/Function
  - Display Layout
    1. Imagery Display
    2. Operator Status/Communication Display
    3. System Status Display
  - Console Setup
    1. Imagery Console Setup
    2. Display Recenter
    3. Map Registration
    4. Creation and Use of Graphics
  - Information Display
    1. Message Type and Format
- Modes of System Operation
  - Target Search
    1. Time Compression
       a. Parameters and Increments
       b. Static/Dynamic Mode
  - Target Tracking
    1. Single Frame Mode
    2. Cursor Form/Use
    3. Target File Initialization/Update
    4. Pickpoint Storage/Detection
  - Target Prediction
    1. Path Creation/Modification
    2. Path Files
    3. Time Prediction
    4. Position Prediction
    5. Information Display
       a. Tactical Messages
       b. Cue Messages
       c. Error Messages
  - Range/Azimuth Determination
    1. Cursor Use
    2. Information Display
- Crew Coordination
  - Intelligence Briefing
  - Operator Guidance
    1. System Configuration
    2. Tactical Graphics
    3. Target Activity
  - Target Handoff
    1. File Transfer
    2. File Destroy
  - OIC Communication
    1. Map Digitizer
    2. Status Display
    3. LO Coordination
  - External Communications
    1. DTOC Interface
       a. Voice
       b. Direct Data Transmission
    2. Helicopter Control
       a. Voice
       b. Data Link
- System/Van Operation
  - Hardware Turn-On
  - Software Load/Initialization
  - System Restart/Reboot
    1. Error Types
    2. Error Causes
    3. Recovery Procedures
  - Disk Changeover
    1. Data Unload
    2. System Restart
  - Off-Line Operation
    1. Imagery Load
    2. System Start Up
  - System Shutdown
    1. Data Unload
    2. Data Storage
    3. Hardware Turn-Off

Assessment Modules - As part of the training sequence, continuous trainee assessment is incorporated in terms of performance measure and evaluation, and critique. Individual and crew performance is measured on specific simulation exercise events and recorded as summarized descriptive statistics. These performance measures are then evaluated in terms of their relationship to a set of acceptance criteria. Critiques of this comparative performance using 30 to 40-minute discussion among crew members and instructors has proven to be effective in the training process.

CONCLUSIONS - SECTION IV

Human Factors Engineering should be applied early in the development cycle of those programs where human performance plays a significant part in the operation and support of the weapon system. In many programs, including SOTAS, optimal human performance has been critical in meeting basic mission functional requirements. In SOTAS this need was reflected in the design of a combined man/machine system with sufficiently short throughput response and high target predictive accuracy in order to be useful as a target acquisition system. Beyond this, human performance has also been found to be critical in assuring the effective integration of the developmental system into the operating force structure in terms of both operational interfacing and cost.

The SOTAS developmental philosophy has emphasized the integration of "demonstrated" hardware subsystems together with a personnel subsystem to achieve an effective standoff target acquisition capability in the shortest possible time. Human Factors Engineering was incorporated as a part of system design in the early phase of concept development. Throughout the validation process of integrating demonstration hardware human factors have been considered in the allocation of operational functions and procedures in the design of workspace, displays, keyboards and other elements of the total man/machine interface. The development of a detailed system simulation has also been a very successful tool in optimizing system design and in establishing effective training procedures and personnel requirements.

In the SOTAS development as in some other programs, Human Factors Engineering also plays an important and a sensitive role in test and evaluation of the system. In this case much of the testing and evaluating procedures were designed by the human factors engineering team in conjunction with other team members as well as with the Operational Test and Evaluation Agency. In this kind of role the credibility of an unbiased human factors team is politically important in assuring the acceptability of the evaluations.

Management methods used in developing the SOTAS system to its present stage have been relatively unstructured and informal, but none the less effective.

The complementing personalities of the program manager, the DASC and the primcipal managers in each responsibility area have done much in assuring this effectiveness.

A few of what appear to be significant issues in the SOTAS application of Human Factors Engineering are listed below and are probably worthy of consideration in future programs:

(a) The composition of the program development team is critical and this is especially true for the human factors team. Much of what the human factors team is able to accomplish in the program depends upon their related experience and upon their relationship and ability to communicate with other team elements. Compatability of personalities of principal area managers seems to be quite important in establishing a flexible give and take relationship which is essential in early phases of the program.

(b) The human factors design area must be perceived within the program organization as having equal status with other design disciplines. Beyond a formal organization structure the enthusiasm and support of the program manager in all design areas can do much in building a "balanced" development team.

(c) The "unbiased credibility" of human factors or other team members involved in critical aspects of test and evaluation must be maintained through initial phases of the program including validation and demonstration. This requirement must be clearly understood at the outset by those team members affected. The formalities of hardware exclusion clauses might be considered in this regard for contractor teams, but would likely be unnecessary if ground rules were clearly understood initially.

(d) The contractual relationship (or Letter of Agreement) with the human factors engineering team must be a flexible one in the initial phases of development. Performance specifications as regards human factors design should be generally stated in terms of system requirements wherever possible. In this way a flexible relationship among team members and the PMO can be maintained.

(e) The development and utilization of a very complete and accurate system simulation by the human factors engineering team has proven to be an extremely valuable design tool not only for man/machine interface and operational procedures but also for training and support design as well as

for guidance in test and evaluation.

This report has summarized some of the philosophy and procedures which have been successfully used in the SOTAS program to incorporate Human Factors Engineering into a balanced approach for meeting mission objectives. By reviewing these philosophies and procedures, some practical guidance can be obtained and applied in other programs where human performance is critical to success.

APPENDIX A

GLOSSARY OF TERMS

ASARC - Army System Acquisition Review Council

C/SCSC - Cost, Schedule Control System Criteria

DA - Department of the Army

DARCOM - Development and Readiness Command

DASC - Department of the Army System Coordinator

DCP - Decision Coordination Paper

DCSRDA - Deputy Chief of Staff for Research Development and Acquisition

DDR&E - Director of Defense Research and Engineering

DOD - Department of Defense

DTOC - Division Tactical Operations Center

DT/OT - Development/Operational Test

ECOM - Electronics Command

ILS - Integrated Logistic Support

I/O - Input/Output

LCC - Life Cycle Cost

MTI - Moving Target Indicator

OIC - Officer-in-Charge

O&S - Operation and Support

OTEA - Operational Test and Evaluation Agency

PM - Program Manager

PMO - Program Management Office

PMP - Program Management Plan

ROC - Requirement for Operating Capability

SAG - Study Advisory Group

SOTAS - Standoff Target Acquisition System

STO - Search and Track Operator

T&E - Test and Evaluation

TRADOC - Training and Doctrination

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